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# A review on Role of *Phytophthora* in Forest Declines

Muhamad Koder

*Department of Biology, College of Education, Al-Iraqia University, Baghdad, IRAQ*

**Abstract**
The impact of *Phytophthora* diseases can have significant impacts on ecosystems, through declines in biodiversity. Predisposing factors are climate or site factors that are long-term, static or slowly changing and render a tree vulnerable to a disease or disturbance. While Inciting factors are short-term physiological or biological factors that can increase the susceptibility of plants to pathogens by causing severe stress. This review confirmed that inciting factors and Predisposing factors could enhance the occurrence of trees decline by *Phytophthora* species.

***Keywords***: urban; sub urban ; forest , Inciting factors, Predisposing factors

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## 1. Introduction

One of the most important contributing[1]to tree declines worldwide are diseases caused by pathogens in the genus *Phytophthora*. Once an invasive *Phytophthora* species arrives in a novel ecosystem it can cause significant losses to plant species and communities over large geographic areas. *Phytophthora ramorum* has destroyed huge areas of Californian forests[2–4] and is responsible sudden oak death epidemic in the urban environment[5,6] *Phytophthora ramorum* is an introduced exotic pathogen to the USA, via the international nursery trade[5,6]. Another introduced and invasive species is *P. cinnamomi*, it has an extensive host range of over 2000 plant species [7], and contributes to White Oak Decline (*Quercus alba*) in the USA[8]. It has also destroyed huge areas of Australia's forests and woodlands[9]. For example, in the south-west of Western Australia, out of the 6510 described plant species, approximately 41% are susceptible to *P. cinnamomi* [9]. In Australia, *P. cinnamomi* is recognized as a 'Key threatening process to Australia's Biodiversity' by the Commonwealth Government's EPBC Act[9], because of its direct impact on plant communities and indirect effects on native fauna through the loss of food, refugia, and habitat. For example, in Australia 157 *Banksia* species are recorded to be a major source of food for many kinds of an animal such as honeyeaters, rodents, honey possums, pygmy possums, gliders and bats[10,11]. Many *Banksia* species are threatened by *Phytophthora* species[9,12]. The impacts of *P. cinnamomi* in urban forests are poorly understood but likely to be significant in green space where it is present. The impact of *Phytophthora* diseases can have significant impacts on ecosystems, through declines in biodiversity[13] and a decline in fundamental ecosystem services, such water equilibrium and river flow, modification of territorial climate patterns and carbon storage in biomass and soils. The impact of *Phytophthora* diseases can have significant impacts on ecosystems, through declines in biodiversity [13] and a decline in fundamental ecosystem services, such water equilibrium and river flow, modification of territorial climate patterns and carbon storage in biomass and soils[14,15].

## 2. The effect of predisposing and inciting factors on trees decline caused by Phytophthora species

### Predisposing factors

Predisposing factors are climate or site factors that are long-term, static or slowly changing and render a tree vulnerable to a disease or disturbance [16,17]. Trees damaged by these factors may slowly recover [16] if further stresses are not imposed on the system. Predisposing factors play an important role in increasing the susceptibility of trees to *Phytophthora* species.

#### *Water availability*

Water is a key determining factor of forest health and includes waterlogging and flooding. Too little or too much water can predispose plants to pathogens, leading to forest diseases[18]. Waterlogging is the saturation of soil with water and can be exacerbated by poor drainage related to soil texture[19] or in areas immediately adjacent to irrigation emitters[20]. Waterlogging leads to low oxygen levels in soil, followed by anoxia or hypoxia and plant stress[21]. There are few tree species that can tolerate long-term

 

low oxygen concentrations and even these species produce little canopy under heavy stress conditions[22]. Overall, soil saturation with water can predispose urban trees to infection by *Phytophthora* species. Corcobado *et al*[23] clearly showed how saturated soils were beneficial to *P. cinnamomi*, and disadvantageous to the tree leading to extensive root damage and death and decline of trees. Numerous other studies have shown tree declines linked with *Phytophthora* diseases are associated with waterlogging[24]. In addition, excess water assists in the dispersal of *Phytophthora* species [25,26]. Excess water through flooding can reduce the growth rate of trees in an urban area. How plants respond morphologically and physiologically to extreme flooding is a significant part of determining the susceptibility of plants to pathogens [27].

***Extreme weather***

Recent climate models forecast greater fluctuations in a climate with increases in the frequency and severity of extreme events such as drought and heavy rains[28]. The direct harm of extreme weather events on trees appears clearly through alterations in phenology, morphology, genetic frequencies and abundance of plants[23,29]. Weather extremes will affect the growth and susceptibility of trees such as *Quercus ilex* to species such as *P. cinnamomi*[29]. Also, extreme weather events could help pathogens to increase the number of their life cycles per year[29].

***Extreme warming***

Urban areas are generally warmer than adjacent rural areas, for example, the daily minimum temperature in New York City is on average ~7.2°F (~4°C) in summer months that makes it warmer than rural areas by an average 1.1°C[30]. Elevated temperatures cause stress in trees and thus predisposes them to pathogens. Elevated temperature stress can have profound health consequences for plants through wilting, leaf burn, leaf folding and abscission, and physiological responses including changes in RNA metabolism and protein synthesis, enzymes, isoenzymes, and plant growth hormones. These changes will surely influence susceptibility to pathogens[31,32].

**Inciting factors**

Inciting factors are short-term physiological or biological factors that can increase the susceptibility of plants to pathogens by causing severe stress [16]. Trees influenced only by inciting factors may recover rapidly [16]. Indeed, the impact of inciting factors which include defoliation and excessive salt, on urban forest decline is a central challenge in forestry and ecology. Inciting factors could enhance the occurrence of trees decline by *Phytophthora* species.

***Defoliation***

Leaf defoliators have been deemed as causative factors of quick mortality in forest trees such as German oak trees [33]. The link between *Phytophthora* species and defoliation was examined by[34,35]. Jung *et al* Indicate that there is possibly a synergistic effect of *Phytophthora* spp. and defoliation events on plants [35] while Oszako *et al* [34] indicated defoliation can enhance the chances of *P. plurivora* to infect birch (*Betula pendula*).

***Excessive salt***

Salt can impact on tree growth by inhibiting chlorophyll synthesis through the direct effect on photochemistry reactions[36]. Many studies reported that excessive salt enhances disease severity[37,38]. These studies proved that soil salinity enhances Phytophthora Root Rot caused by *P. parasitica* in tomato [37]and stem rot caused by *P. citrophthora* in citrus rootstocks[38].

**Loss of mycorrhizal fungi and other microorganisms**

Mycorrhizal fungi are considered one of the most important groups of microorganisms supporting the health of trees, as they help plants obtain nutrients and water through their mutualistic connection with roots of plants[39]. Ectomycorrhizal fungi also reduce the severity of disease caused by *Phytophthora* species as they provide an effective barrier to *Phytophthora* infection. Watanarojanaporn *et al*[40] showed that root rot disease caused by *P. nicotianae* was reduced by arbuscular mycorrhiza. Similar results were found by Branzanti *et al* [41] when investigating the correlation between the severity of *Q. robur* decline and mycorrhizal colonization and they showed that forest decline increased when mycorrhizal colonization decreased.

## 3. Discussion

Once introduced, urban landscapes can play an important role in the pathway of new *Phytophthora* species spreading into natural ecosystems. Many *Phytophthora* species have been recovered from urban environments. For example, 22% of type specimens of *Phytophthora* were isolated from urban environments and were described between 2001 and 2016[42]. The importance of nurseries for the dissemination of *Phytophthora* species cannot be underplayed as plant production nurseries supply material for urban and peri-urban plantings in addition to forestry, horticulture, and environmental restoration. Indeed, various *Phytophthora* species are considered as main pathogens of nursery plants[43]. As the nursery trade continues to grow globally, *Phytophthora* species continue to spread into new areas, and nurseries are one of the principal routes of pathogen movement and introduction of alien plant pathogens into natural ecosystems [44]. Hardy[44] found eight *Phytophthora* species associated with 14 nurseries in Perth, Western Australia. This indicates *Phytophthora* species have been problematic in nurseries for a long time in Perth.

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## 4. Conclusion

The relationship between urban forest declines and *Phytophthora* species is considered important as they can result in economic and environmental losses including the loss of biodiversity and many tree species. There are many biotic and abiotic factors that can adversely impact on tree health leading to increased susceptibility of tree species to *Phytophthora.* However, there are gaps in our knowledge of the abiotic and biotic factors in urban or peri-urban landscapes that help predispose urban trees to *Phytophthora* diseases. This review has described the losses caused by *Phytophthora* species and has outlined some of the predisposing and inciting factors that can potentially influence the susceptibility of urban trees to *Phytophthora* species. It has also discussed some of the methods that can be used to rapidly identify *Phytophthora* species and to monitor their spread and impact across large areas, and how *Phytophthora* species can be managed.

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